CLAIMS

WE CLAIM:

1. A soft-reference four conductor magnetic memory storage device comprising:

a plurality of parallel electrically conductive first sense conductors;

a plurality of parallel electrically conductive second sense conductors crossing the first sense conductors, thereby forming a sense cross point array with a plurality of intersections;

a plurality of soft-reference magnetic tunnel junction memory cells, each cell in electrical contact with and located at an intersection between a first sense conductor and a second sense conductor, the memory cells comprising a material with an alterable orientation of magnetization;

a plurality of parallel electrically conductive write rows substantially proximate to and electrically isolated from the first sense conductors; and

a plurality of parallel electrically conductive write columns crossing the write rows, substantially proximate to and electrically isolated from the second sense conductors, thereby forming a write cross point array with a plurality of intersections.

2. The magnetic memory device of claim 1, wherein each memory cell includes;

at least one ferromagnetic data layer characterized by an alterable orientation of magnetization;

an intermediate layer in contact with the data layer; and

at least one ferromagnetic soft-reference layer in contact with the intermediate layer, opposite from the data layer, the soft-reference layer having a non-pinned orientation of magnetization and lower coercivity than the data layer.

3. The magnetic memory device of claim 2, wherein during a read operation the ferromagnetic soft-reference layer is pinned-on-the-fly to a desired orientation by a sense magnetic field generated by at least one sense current flowing in at least one sense conductor, the magnetic field being insufficient to affect the orientation of the data layer; and

wherein during a write operation a combined write magnetic field is generated by a write current flowing in the write column and row conductors, the combined magnetic field sufficient to orient the data layer.

4. The magnetic memory device of claim 3, wherein the sense current is flowing in at least one sense conductor.

5. The magnetic memory device of claim 2, wherein the first sense conductor has a ferromagnetic cladding that completely surrounds the first sense conductor.

6. The magnetic memory device of claim 5, wherein the ferromagnetic clad first sense conductor is the soft-reference layer.

7. The magnetic memory device of claim 6, wherein during a read operation the ferromagnetic soft-reference layer is pinned-on-the-fly to a desired orientation by a sense magnetic field generated by a sense current flowing in the first sense conductor, the magnetic field being substantially contained within the ferromagnetic cladding and insufficient to affect the orientation of the data layer; and

wherein during a write operation a combined write magnetic field is generated by a write current flowing in the write column and row conductors, the combined magnetic field sufficient to orient the data layer.

8. The magnetic memory device of claim 2, wherein the at least one write conductor is substantially covered with ferromagnetic cladding.

9. A soft-reference four conductor magnetic memory storage device comprising:

a plurality of soft-reference magnetic tunnel junction memory cells connected in series by a plurality of first sense conductors and a plurality second sense conductors; the memory cells comprising a material with an alterable orientation of magnetization;

a plurality of parallel electrically conductive write rows substantially proximate to and electrically isolated from the first sense conductors; and

a plurality of parallel electrically conductive write columns transverse to the write rows, substantially proximate to and electrically isolated from the second sense conductors, thereby forming a write cross point array with a plurality of intersections.

10. The magnetic memory device of claim 9, wherein each memory cell includes;

at least one ferromagnetic data layer characterized by at an alterable orientation of magnetization;

an intermediate layer in contact with the data layer; and

at least one ferromagnetic soft-reference layer in contact with the intermediate layer, opposite from the data layer, the soft-reference layer having a non-pinned orientation of magnetization and lower coercivity than the data layer.

11. The magnetic memory device of claim 10, wherein during a read operation the ferromagnetic soft-reference layer is pinned-on-the-fly to a desired orientation by a sense magnetic field generated by at least one sense current flowing in at least one write conductor, the magnetic field being insufficient to affect the orientation of the data layer; and

wherein during a write operation a combined write magnetic field is generated by a write current flowing in the write column and row conductors, the combined magnetic field sufficient to orient the data layer.

12. The magnetic memory device of claim 9, wherein the at least one write conductor is substantially covered with ferromagnetic cladding.

13. A soft-reference four conductor magnetic memory cell comprising:

at least one ferromagnetic data layer characterized by an alterable orientation of magnetization;

an intermediate layer in contact with the data layer;

at least one ferromagnetic soft-reference layer in contact with the intermediate layer, opposite from the data layer, the soft-reference layer having a non-pinned orientation of magnetization and lower coercivity than the data layer;

at least one first sense conductor in electrical contact with the soft-reference layer, opposite from the intermediate layer;

at least one second sense conductor in electrical contact with the data layer, opposite from the intermediate layer;

at least one write column conductor substantially proximate to and electrically isolated from the second sense conductor; and

at least one write row conductor substantially proximate to and electrically isolated from the first sense conductor.

14. The magnetic memory device of claim 13, wherein during a read operation the ferromagnetic soft-reference layer is pinned-on-the-fly to a desired orientation by a sense magnetic field generated by at least one sense current flowing in at least one sense conductor, the magnetic field being insufficient to affect the orientation of the data layer; and

wherein during a write operation a combined write magnetic field is generated by a write current flowing in the write column and row conductors, the combined magnetic field sufficient to orient the data layer.

15. The magnetic memory device of claim 13, wherein, wherein during a read operation the ferromagnetic soft-reference layer is pinned-on-the-fly to a desired orientation by a sense magnetic field generated by at least one sense current flowing in at least one write conductor, the magnetic field being insufficient to affect the orientation of the data layer; and

wherein during a write operation a combined write magnetic field is generated by a write current flowing in the write column and row conductors, the combined magnetic field sufficient to orient the data layer.

16. The magnetic memory device of claim 13, wherein the first sense conductor is substantially transverse to the second sense conductor.

17. The magnetic memory device of claim 13, wherein the write row is substantially transverse to the write column.

18. The magnetic memory device of claim 13, wherein the at least one write conductor is substantially covered with ferromagnetic cladding.

19. A soft-reference four conductor magnetic memory cell comprising:

at least one soft-reference layer having a non-pinned orientation of magnetization and including a first sense conductor and a ferromagnetic cladding that completely surrounds the first sense conductor;

an intermediate layer in contact with the soft-reference layer;

at least one ferromagnetic data layer characterized by an alterable orientation of magnetization in contact with the intermediate layer opposite from the soft-reference layer and having a higher coercivity than the soft-reference layer;

at least one second sense conductor in contact with the data layer, opposite from the intermediate layer;

at least one write column conductor substantially proximate to and electrically isolated from the second sense conductor; and

at least one write row conductor substantially proximate to and electrically isolated from the soft-reference layer, opposite from the write column.

20. The magnetic memory device of claim 19, wherein during a read operation the ferromagnetic soft-reference layer is pinned-on-the-fly to a desired orientation by a sense magnetic field generated by at least one sense current flowing in at least one sense conductor, the magnetic field being substantially contained within the ferromagnetic cladding and insufficient to affect the orientation of the data layer; and

wherein during a write operation a combined write magnetic field is generated by a write current flowing in the write column and row conductors, the combined magnetic field sufficient to orient the data layer.

21. The magnetic memory device of claim 19, wherein the first sense conductor is substantially transverse to the second sense conductor.

22. The magnetic memory device of claim 19, wherein the write row is substantially transverse to the write column.

23. The magnetic memory device of claim 19, wherein the at least one write conductor is substantially covered with ferromagnetic cladding.

24. A method of non-destructively determining a data value in a magnetic memory storage device having a plurality of soft-reference four conductor magnetic memory cells, each cell including a soft-reference layer, a set of sense conductors in electrical contact with the cell, and a set of write conductors electrically isolated from the cell, the method comprising:

selecting a given magnetic memory cell;

providing an initial sense current to at least one sense conductor;

generating an initial sense magnetic field proximate to the given memory cell;

pinning-on-the-fly the soft-reference layer in orientation with the initial sense magnetic field;

measuring an initial resistance value of the given cell;

storing the initial resistance value;

generating a second known sense magnetic field proximate to the given memory cell and orienting the soft-reference layer in a second known orientation;

measuring a second resistance value of the given cell with the soft-reference in the second known orientation;

storing the second resistance value as a reference resistance;

comparing the initial resistance value to the reference resistance value; and

returning a logic level associated with the compared state.

25. The method of claim 24, wherein the sense magnetic fields are generated by current flowing in at least one sense conductor.

26. The method of claim 24, wherein the sense magnetic fields are generated by current flowing in at least one write conductor.

27. The method of claim 24, wherein the sense magnetic fields do not affect the orientation of the data layer.

28. The method of claim 24, wherein the sense current in the second known direction is opposite to the initial sense current.

29. The method of claim 24, wherein the method is repeated more than once.

30. The method of claim 24, wherein the magnitude of the initial sense current is substantially about zero.

31. A method of non-destructively determining a data value in a magnetic memory storage device having a plurality of soft-reference four conductor magnetic memory cells, each cell including at least one ferromagnetic data layer, an intermediate layer, at least one ferromagnetic soft-reference layer in contact with the intermediate layer opposite from the data layer, at least one first sense conductor in electrical contact with the soft-reference layer, at least one second sense conductor in electrical contact with the data layer, and at least one write column conductor substantially proximate to and electrically isolated from the second sense conductor; and at least one write row conductor substantially proximate to and electrically isolated from the first sense conductor, the method comprising:

selecting a given magnetic memory cell;

providing an initial sense current to the first sense conductor, the current generating an initial sense magnetic field;

pinning-on-the-fly the soft-reference layer in orientation with the initial sense magnetic field;

measuring an initial resistance value of the given cell;

storing the initial resistance value;

providing a sense current in a second known direction to the first sense conductor, the current generating a second known sense magnetic field and orienting the soft-reference layer in a second known orientation;

measuring a resistance value of the given cell with the soft-reference layer in the second known orientation;

storing the resistance value of the second known direction as a reference resistance;

comparing the initial resistance value to the reference resistance value; and

returning a logic level associated with the compared state.

32. The method of claim 31, wherein the sense magnetic fields do not affect the orientation of the data layer.

33. The method of claim 31, wherein the sense current in the first known direction is opposite to the initial sense current.

34. The method of claim 31, wherein the method is repeated more than once.

35. The method of claim 31, wherein the magnitude of the initial sense current is substantially about zero.

36. A method of non-destructively determining a data value in a magnetic memory storage device having a plurality of soft-reference four conductor magnetic memory cells, each cell including at least one ferromagnetic data layer, an intermediate layer, at least one ferromagnetic soft-reference layer in contact with the intermediate layer opposite from the data layer, at least one first sense conductor in electrical contact with the soft-reference layer, at least one second sense conductor in electrical contact with the data layer, and at least one write column conductor substantially proximate to and electrically isolated from the second sense conductor; and at least one write row conductor substantially proximate to and electrically isolated from the first sense conductor, the method comprising:

selecting a given magnetic memory cell;

providing an initial sense current to the first sense conductor;

providing a first read current to the write row conductor, the current generating an initial sense magnetic field;

pinning-on-the-fly the soft-reference layer in orientation with the initial sense magnetic field;

measuring an initial resistance value of the given cell;

storing the initial resistance value;

providing a second read current in a second known direction to the write row conductor, the current generating a second known sense magnetic field and orienting the soft-reference layer in a second known orientation;

measuring a resistance value of the given cell with the soft-reference layer in the second known orientation;

storing the resistance value of the second known orientation as a reference resistance;

comparing the initial resistance value to the reference resistance value; and

returning a logic level associated with the compared state.

37. The method of claim 36, wherein the sense magnetic fields do not affect the orientation of the data layer.

38. The method of claim 36, wherein the second read current in the first known direction is opposite to the first read current.

39. The method of claim 36, wherein the method is repeated more than once.

40. The method of claim 36, wherein the magnitude of the initial sense current is substantially about zero.

41. A computer system comprising:

a main board;

at least one central processing unit (CPU) joined to the main board;

at least one soft-reference four conductor magnetic memory storage device joined to the CPU by the main board; the soft-reference four conductor magnetic memory including:

a plurality of parallel electrically conductive first sense conductors;

a plurality of parallel electrically conductive second sense conductors transverse to the first sense conductors, thereby forming a sense cross point array with a plurality of intersections;

a plurality of soft-reference magnetic tunnel junction memory cells, each cell in electrical contact with and located at an intersection between a first sense conductor and a second sense conductor, the memory cells comprising a material with an alterable orientation of magnetization and a soft-reference layer;

a plurality of parallel electrically conductive write rows substantially proximate to and electrically isolated from the first sense conductors; and

a plurality of parallel electrically conductive write columns transverse to the write rows, substantially proximate to and electrically isolated from the second sense conductors, thereby forming a write cross point array with a plurality of intersections.

42. The magnetic memory storage device of claim 41, wherein during a read operation the soft-reference layer of a given cell is pinned-on-the-fly to a desired orientation by a sense magnetic field generated by at least one sense current flowing in at least one conductor, the sense magnetic field being insufficient to affect the orientation of a data layer; and

wherein during a write operation a combined write magnetic field is generated by a write current flowing in the electrically conductive write columns and rows, the combined magnetic field sufficient to orient the data layer.